Eurocrypt 2025

Committing Authenticated Encryption: Generic Transforms with Hash Functions

Shan Chen[1]

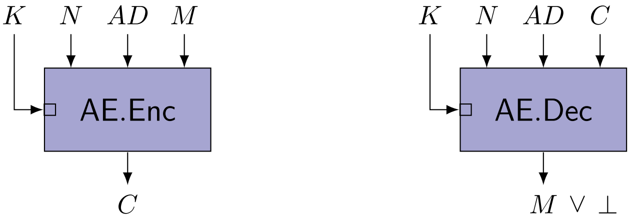
Vukašin Karadžić[2]

[1] Southern University of Science and Technology, Shenzhen, China

[2] Technische Universität Darmstadt, Germany

Authenticated Encryption and Committing Security

Authenticated Encryption



K	key
N	nonce
AD	associated data
M	message
C	ciphertext

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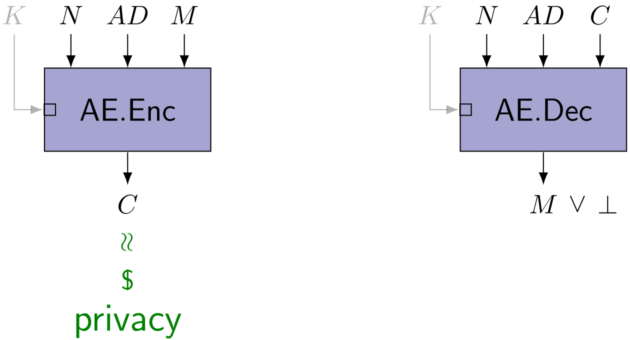

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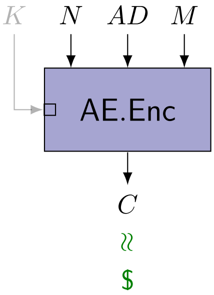
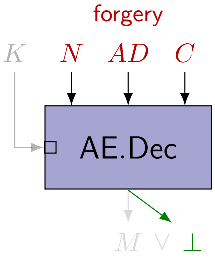


privacy



authenticity

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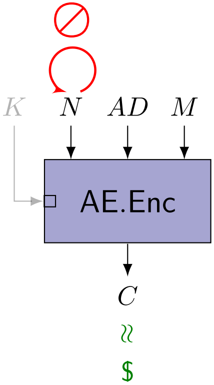

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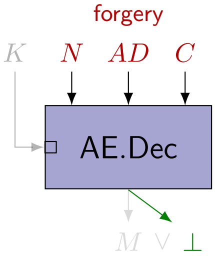

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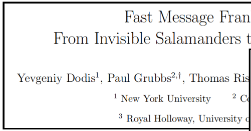

Fast Message Franking:
From Invisible Salamanders to Encryptment*

Yevgeniy Dodis[1], Paul Grubbs[2,†], Thomas Ris

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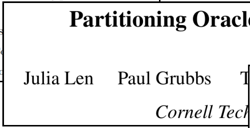
[DGRW18]



Partitioning Oracle Attacks

Julia Len Paul Grubbs T

Cornell Tecl

[LGR21]

How to Abuse and Fix Authenticated Encryption Without Key Commitment

Ange Albertini and Thai Duong, *Google Research;* Shay Gueron, *University of Haifa and Amazon;* Stefan Kölbl, Atul Luykx, and Sophie Schmieg, *Google Research*

https://www.usenix.org/conference/usenixsecurity22/presentation/albertini

[ADG$^+$22]

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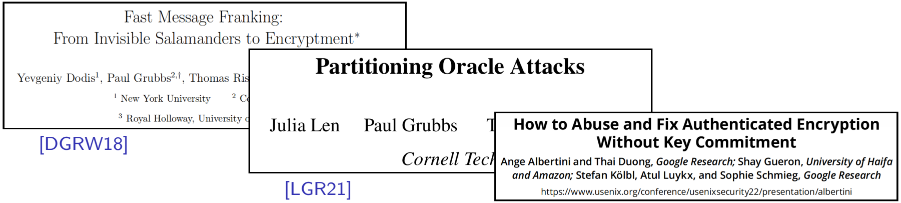

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CMT(-3/4) [CR22, BH22]

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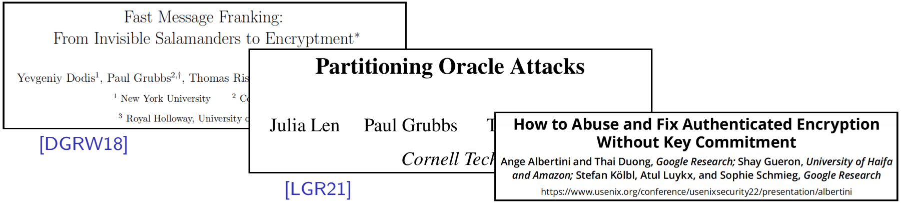

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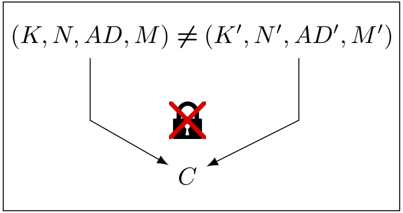

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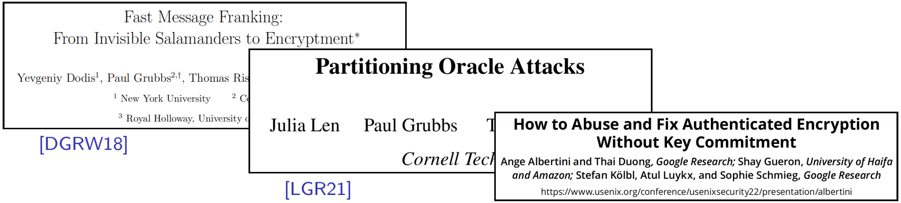

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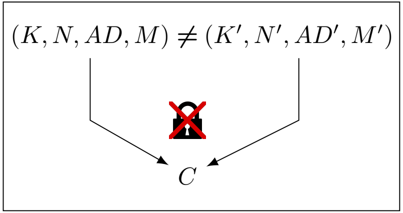

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Previous work:

- popular and deployed AE schemes not committing: AES-GCM, OCB, ChaCha20/Poly1305, etc. [GLR17, DGRW18, LGR21, ADG+22]

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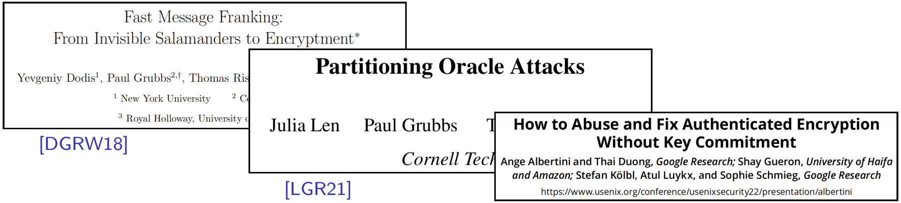

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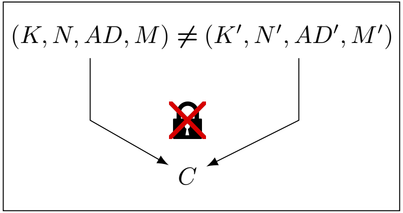

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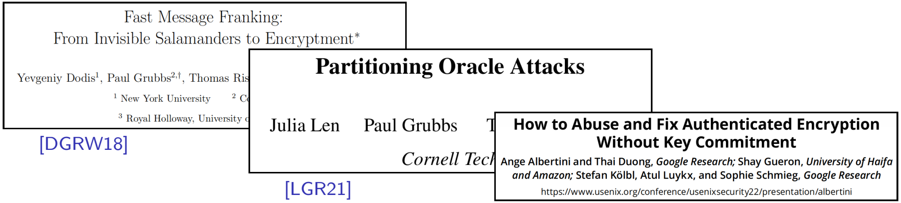

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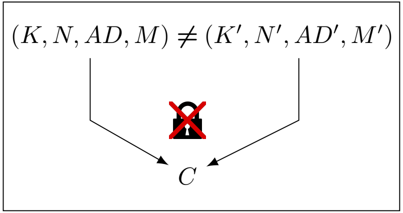

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- popular and deployed AE schemes not committing: AES-GCM, OCB, ChaCha20/Poly1305, etc. [GLR17, DGRW18, LGR21, ADG$^+$22]
- dedicated modifications (e.g., [BH22])
- **generic transforms** (e.g., [ADG$^+$22, BH22, BCC$^+$24])

Our Motivation

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  1. not committing to the entire encryption context (i.e., the whole (K, N, AD, M) tuple)

For example:

CommitKeyΠ [ADG$^+$22]

only key-committing

Context commitment naming stems from [MLGR23].

Our Motivation

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  2. involving non-standard primitives

For example:

SIV [BCC+24]

key-committing MAC

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  1. not committing to the entire encryption context (i.e., the whole (K, N, AD, M) tuple)
  2. involving non-standard primitives
  3. not a black-box transform

For example:

CTX [CR22]

“tag-based” AE

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  3. not a black-box transform
  4. provide limited committing security

For example:

PACT/comPACT [BBD24]

committing tag
from blockcipher

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  2. involving non-standard primitives
  3. not a black-box transform
  4. provide limited committing security

$\Rightarrow$ Investigate how to achieve **committing AE** using **black-box** generic transforms with **standard primitives**

Context commitment naming stems from [MLGR23].

Choosing Building Blocks

(Authenticated) Encryption

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(**Authenticated**) **Encryption**

- look at both plain privacy-only encryption (E) and authenticated encryption (AE) schemes

  → *crypto-agility*

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Hash Functions

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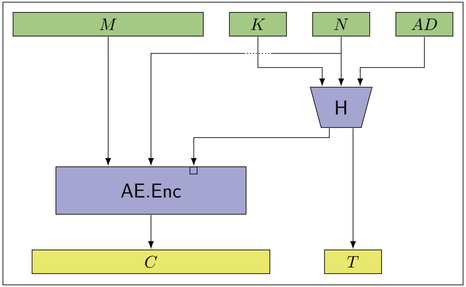
Hash Functions

- to achieve CMT-secure AE: idealized assumption, like *ideal cipher* or *random oracle* model is currently unavoidable (for practical instantiations)
- we opt-out for hash functions (and random oracle model):
  - known and widely deployed primitive
  - easily gives us committing property (*collision resistance*)
  - CMT security can easily be increased by taking longer digest

Our Transforms: HtAE

HtAE
(Hash-then-AE)



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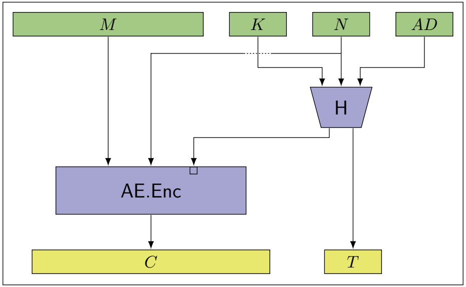

- HtAE **rekeys** underlying AE for every encryption query

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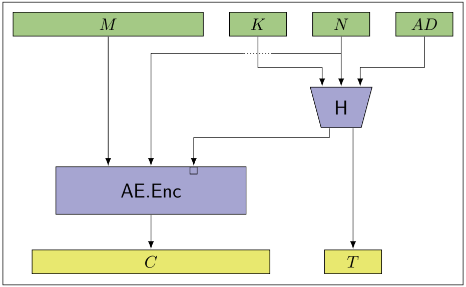

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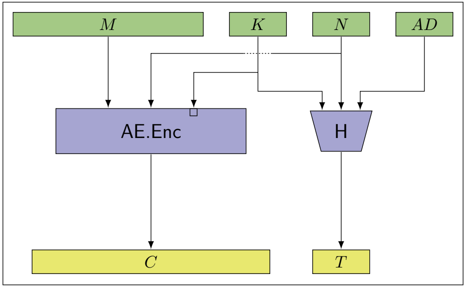
costly, but still similar performance in comparison to existing transforms that rekey internally

Our Transforms: AEaH

AEaH
(AE-and-Hash)



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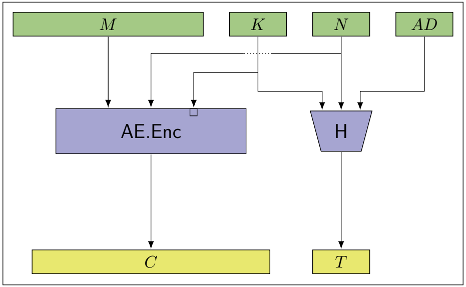
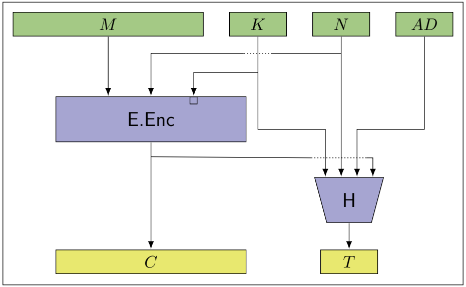


- AEaH is *fully* **parallelizable**

Our Transforms: EtH

EtH

(Encrypt-then-Hash)



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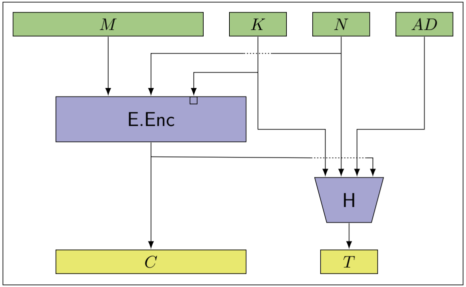

- Encryption primitive E only privacy-secure

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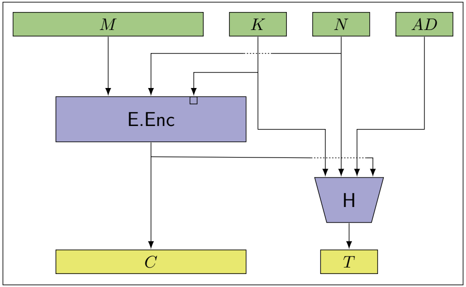

- Encryption primitive E only privacy-secure, but can also be AE

Our Transforms: EtH

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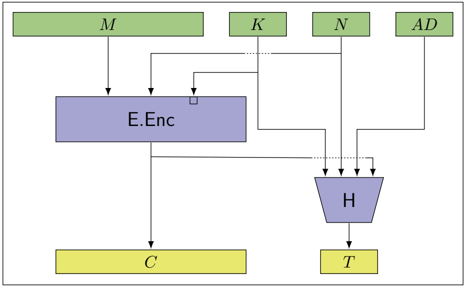

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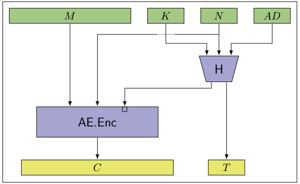
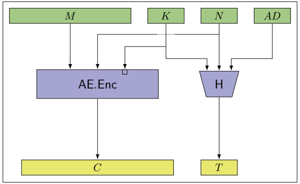
Security Results

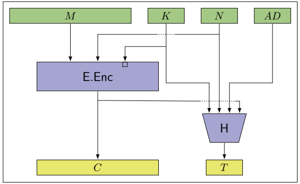
HtAE



AEaH



EtH



- Our HtAE, AEaH and EtH transforms are:

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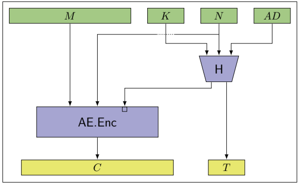

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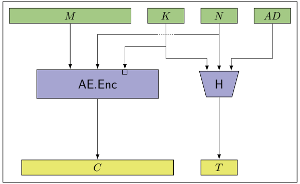

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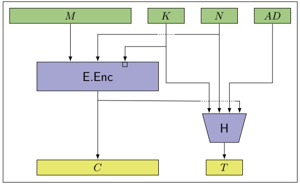

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privacy, authenticity and CMT-secure

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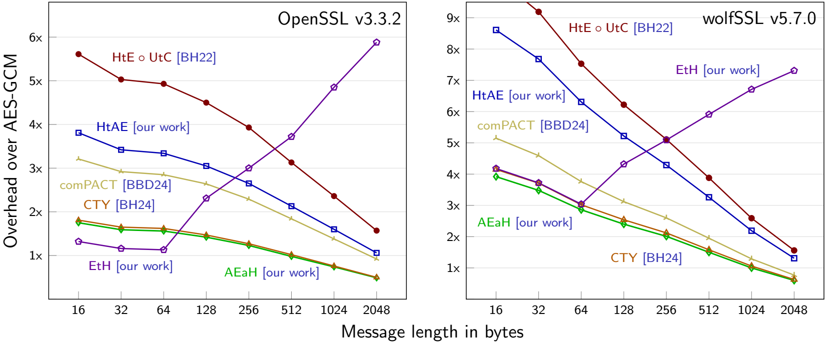

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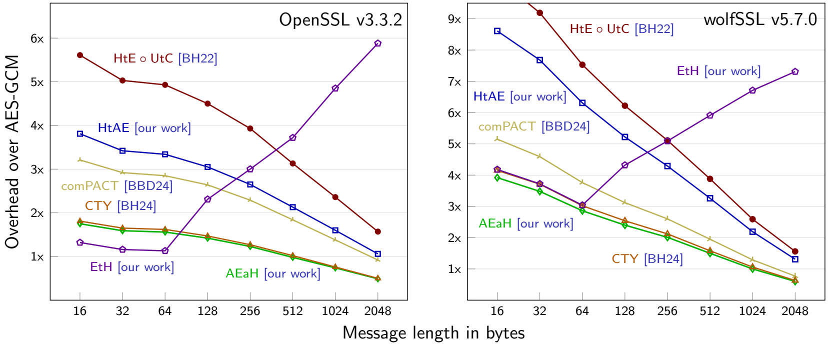

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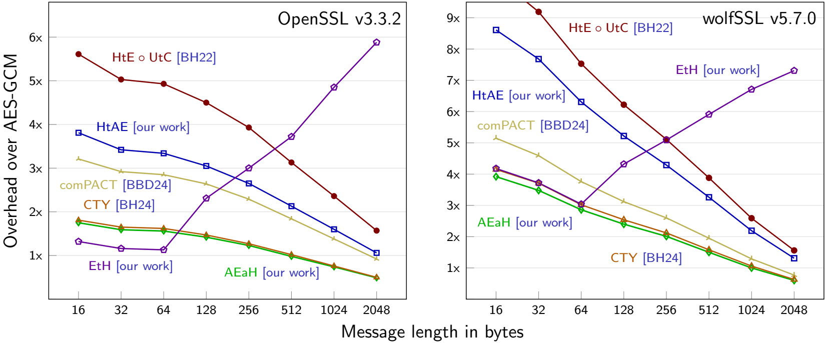

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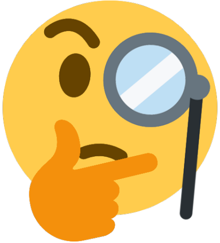
- here our (*parallelizable*) AEaH is implemented sequentially; dedicated implementation would perform even better

What if ...

... a nonce repeats in the encryption?



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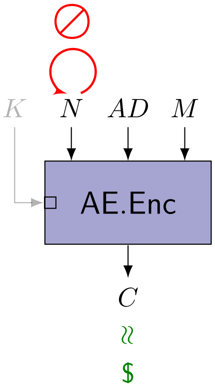

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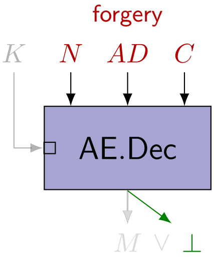

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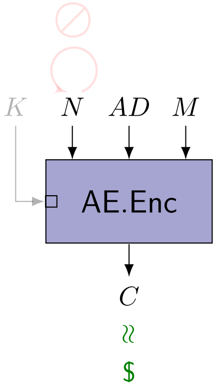

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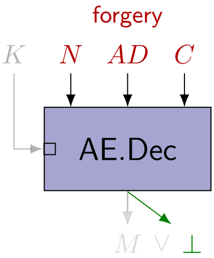

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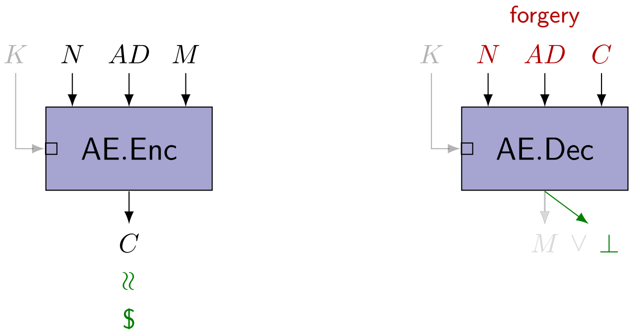
(nonce) misuse-resistant authenticated encryption

MRAE



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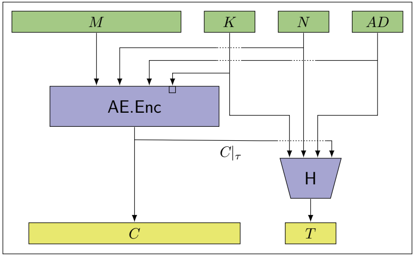
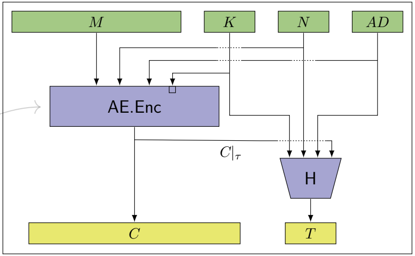
MRAE-Preserving Transform: AEtH

AEtH



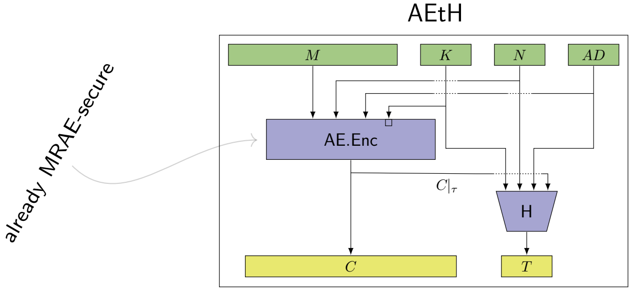
MRAE-Preserving Transform: AEtH

AEtH



already MRAE-secure

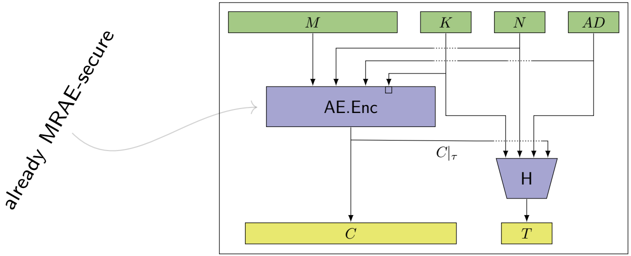
MRAE-Preserving Transform: AEtH



- Black-box generalization of CTX [CR22] (authors of [CR22] did not show MRAE security)

MRAE-Preserving Transform: AEtH

AEtH

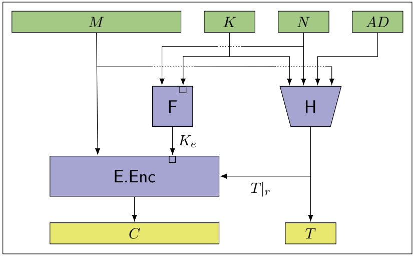


- Black-box generalization of CTX [CR22] (authors of [CR22] did not show MRAE security)

$$\boxed{\text{MRAE-secure AE} + \text{coll. res. H} \xRightarrow{\text{ROM}} \text{AEtH is MRAE- and CMT-secure}}$$

MRAE-Lifting Transform: chaSIV

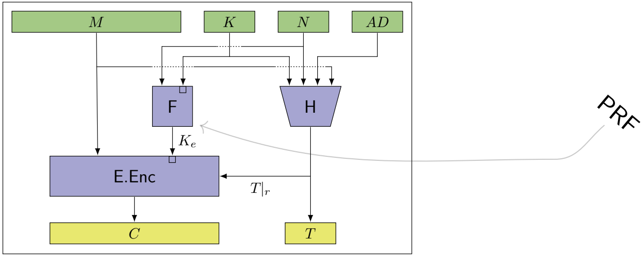
chaSIV



- **c**ommitting **ha**sh-based **SIV**

MRAE-Lifting Transform: chaSIV

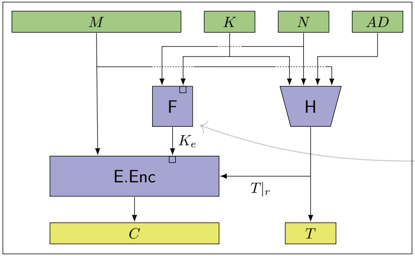
chaSIV



- **c**ommitting **ha**sh-based **SIV**

MRAE-Lifting Transform: chaSIV

chaSIV



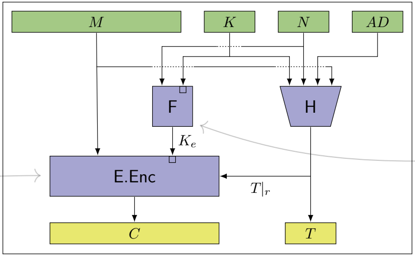
could be inst. with AES, so no new primitive implementation is needed

PRF

- **c**ommitting **ha**sh-based **SIV**

MRAE-Lifting Transform: chaSIV

chaSIV



only privacy-secure

PRF

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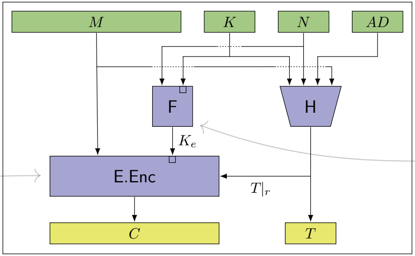
- **c**ommitting **ha**sh-based **SIV**

MRAE-Lifting Transform: chaSIV

chaSIV



only privacy-secure
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PRF
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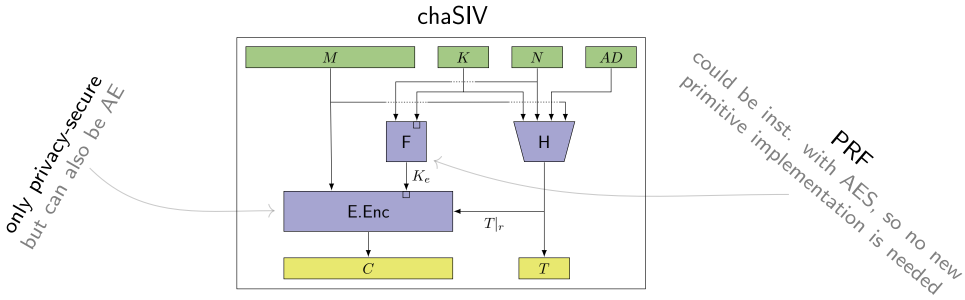
- **c**ommitting **ha**sh-based **SIV**

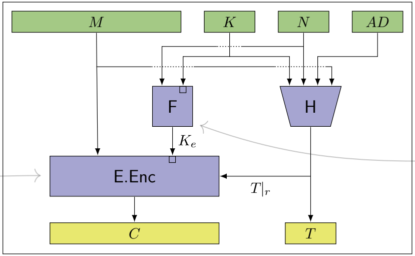
MRAE-Lifting Transform: chaSIV



- **c**ommitting **ha**sh-based **SIV**
- *first generic transform* that promotes plain E to **committing MRAE-secure** scheme

MRAE-Lifting Transform: chaSIV

chaSIV



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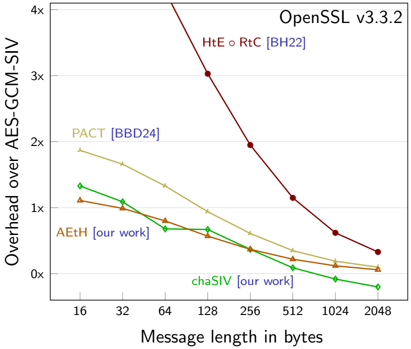
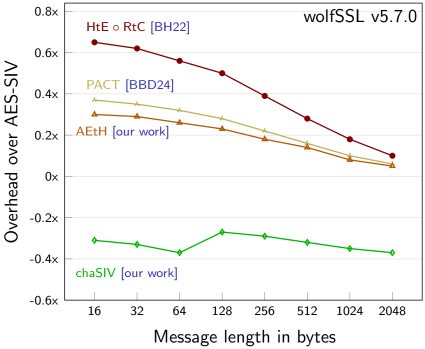
PRF

- **c**ommitting **ha**sh-based **SIV**
- *first generic transform* that promotes plain E to **committing MRAE-secure** scheme

privacy-secure $\mathsf{E} + $ coll. res. $\mathsf{H} + $ PRF $\mathsf{F} \xrightarrow{\text{ROM}}$ chaSIV is MRAE- and CMT-secure

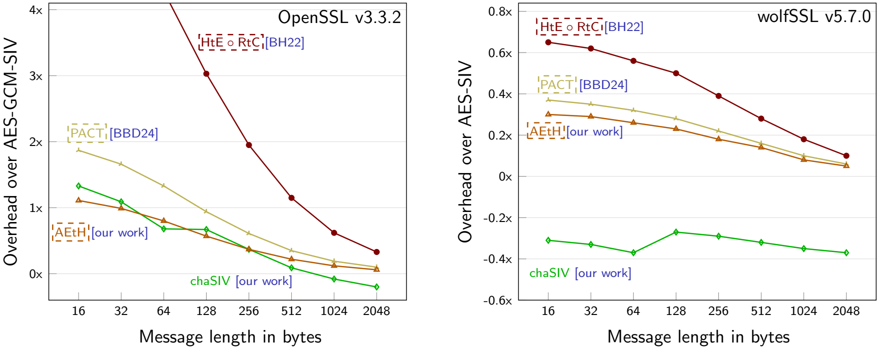
(Encryption) Performance Evaluation: MRAE-secure Transforms





Note: *all transforms are implemented using only* **black-box** *primitive implementations of the underlying library*

(Encryption) Performance Evaluation: MRAE-secure Transforms



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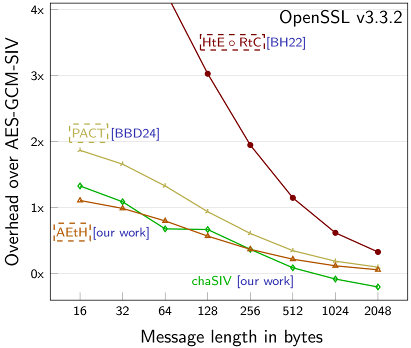
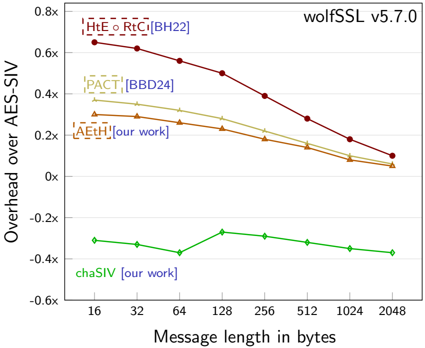
(Encryption) Performance Evaluation: MRAE-secure Transforms

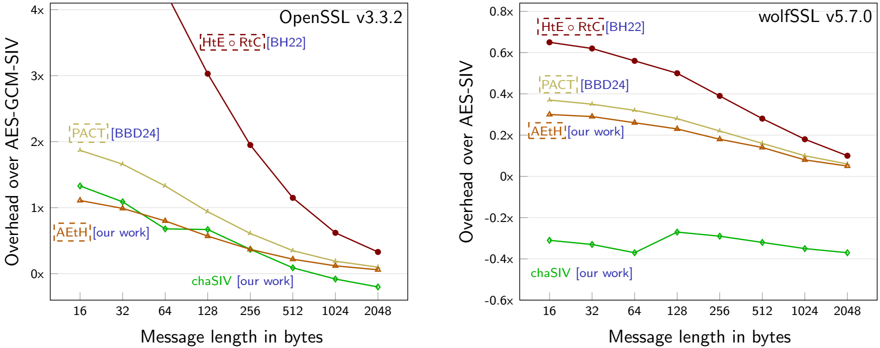




Note: *all transforms are implemented using only* **black-box** *primitive implementations of the underlying library*

- MRAE-preserving transforms: our AEtH (*black-box generalization of* CTX) performs the best

(Encryption) Performance Evaluation: MRAE-secure Transforms

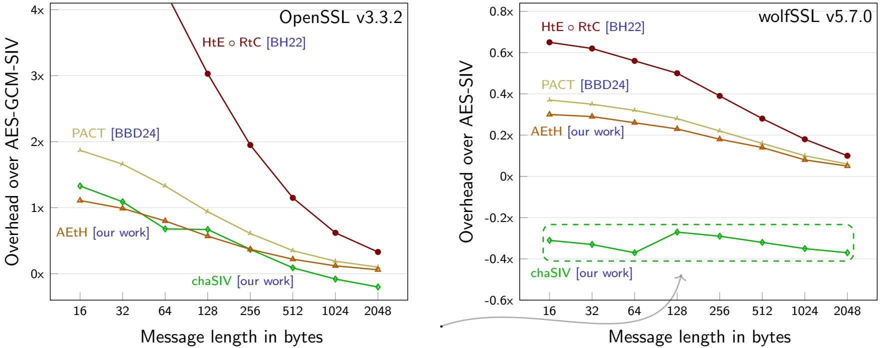


Note: *all transforms are implemented using only* **black-box** *primitive implementations of the underlying library*

- MRAE-preserving transforms: our AEtH (*black-box generalization of* CTX) performs the best

  additionally: CTX decryption algorithm would need *two* passes using OpenSSL's API, and would even be *impossible* to implement in wolfSSL

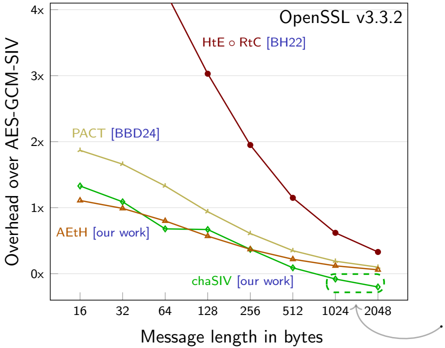
(Encryption) Performance Evaluation: MRAE-secure Transforms

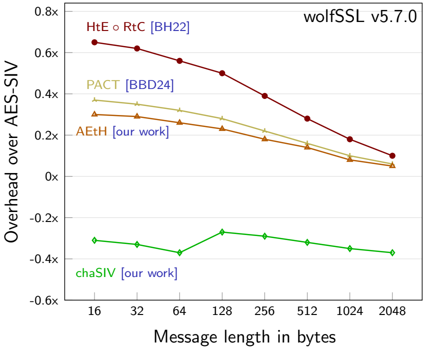


Note: *all transforms are implemented using only* **black-box** *primitive implementations of the underlying library*

- In wolfSSL: AEtH beats the benchmark AES-SIV for all message lengths

(Encryption) Performance Evaluation: MRAE-secure Transforms





Note: *all transforms are implemented using only* **black-box** *primitive implementations of the underlying library*

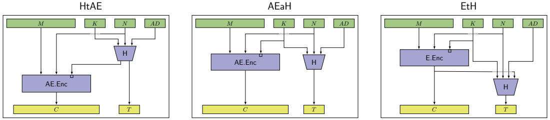
- In wolfSSL: AEtH beats the benchmark AES-SIV for all message lengths
- In OpenSSL: AEtH beats the benchmark AES-GCM-SIV for long messages

Takeaway

Takeaway

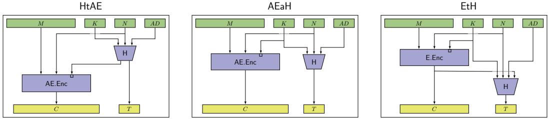
Takeaway

3 basic committing AE-secure transforms


HtAE
AEaH
EtH

Takeaway

3 basic committing AE-secure transforms

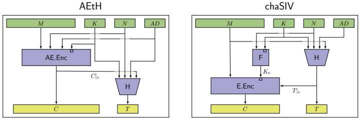


HtAE

AEaH

EtH

2 advanced committing MRAE-secure transforms

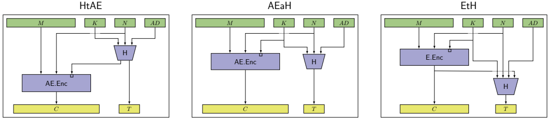


AEtH

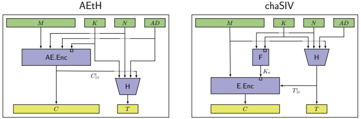
chaSIV

Takeaway

3 basic committing AE-secure transforms



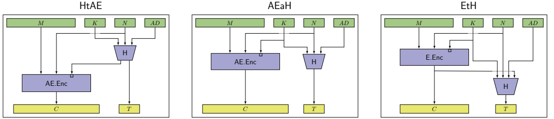
2 advanced committing MRAE-secure transforms



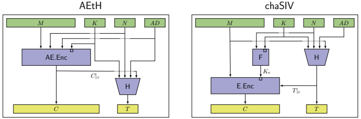
- easy to grasp and implement (*standardized primitives*)

Takeaway

3 basic committing AE-secure transforms



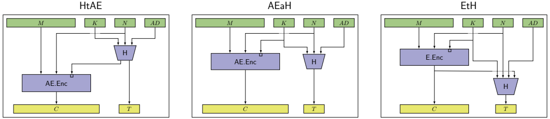
2 advanced committing MRAE-secure transforms



- easy to grasp and implement (*standardized primitives*)
- our transforms, implemented only with **black-box** primitives from common cryptographic libraries, are very **efficient**

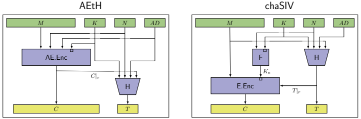
Takeaway

3 basic committing AE-secure transforms



HtAE AEaH EtH

2 advanced committing MRAE-secure transforms



AEtH chaSIV

- easy to grasp and implement (*standardized primitives*)
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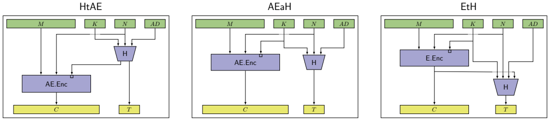
- hope: **fast adoption of committing AEAD**
- please contact us if you're interested in our work

Takeaway

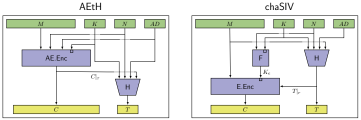
3 basic committing AE-secure transforms


HtAE

AEaH

EtH

2 advanced committing MRAE-secure transforms


AEtH

chaSIV

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Thanks!

Questions?

many more details (e.g. CDY security) → ePrint

Code Artifact ← IACR Results Reproduced

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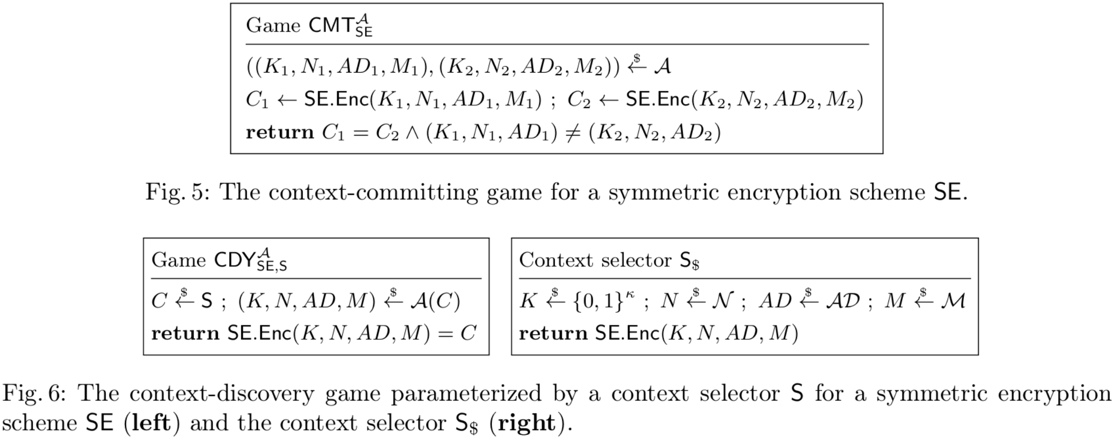
Backup Slides

CMT and CDY Security Notions



```
Game $\mathsf{CMT}^{\mathcal{A}}_{\mathsf{SE}}$
$((K_1, N_1, AD_1, M_1), (K_2, N_2, AD_2, M_2)) \xleftarrow{\$} \mathcal{A}$
$C_1 \leftarrow \mathsf{SE.Enc}(K_1, N_1, AD_1, M_1)$ ; $C_2 \leftarrow \mathsf{SE.Enc}(K_2, N_2, AD_2, M_2)$
return $C_1 = C_2 \wedge (K_1, N_1, AD_1) \neq (K_2, N_2, AD_2)$
```

Fig. 5: The context-committing game for a symmetric encryption scheme SE.

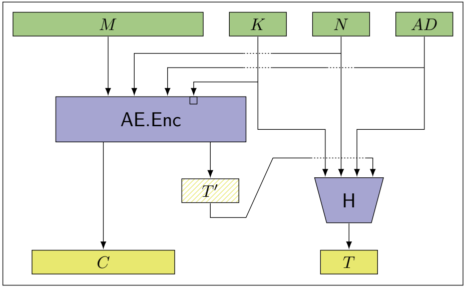
```
Game $\mathsf{CDY}^{\mathcal{A}}_{\mathsf{SE,S}}$
$C \xleftarrow{\$} \mathsf{S}$ ; $(K, N, AD, M) \xleftarrow{\$} \mathcal{A}(C)$
return $\mathsf{SE.Enc}(K, N, AD, M) = C$
```

```
Context selector $\mathsf{S}_{\$}$
$K \xleftarrow{\$} \{0,1\}^{\kappa}$ ; $N \xleftarrow{\$} \mathcal{N}$ ; $AD \xleftarrow{\$} \mathcal{AD}$ ; $M \xleftarrow{\$} \mathcal{M}$
return $\mathsf{SE.Enc}(K, N, AD, M)$
```

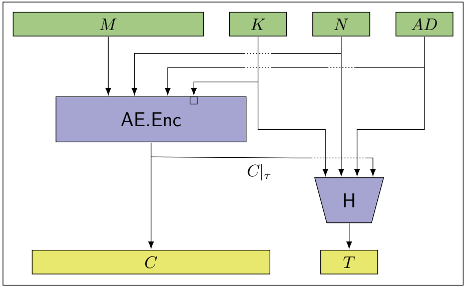
Fig. 6: The context-discovery game parameterized by a context selector S for a symmetric encryption scheme SE (**left**) and the context selector $\mathsf{S}_{\$}$ (**right**).

CTX vs. black-box generalization AEtH

CTX [CR22]



AEtH [our work]



Performance Evaluation Details: AE-secure Transforms

- Implemented *encryption* algorithm of our transforms and existing transforms

  $$\mathsf{HtE} \circ \mathsf{UtC}\ \text{[BH22]},\ \mathsf{CTY}\ \text{[BH24]},\ \mathsf{comPACT}\ \text{[BBD24]}$$

  that target *the same* (i.e., strongest) CMT security in OpenSSL and wolfSSL:

  - Use AES-GCM as AE in both libraries
  - Use AES-CTR as E in OpenSSL and AES-GCM as E in wolfSSL
  - Use truncated SHA-512 as H

- Performance measured as overhead over baseline (non-committing) AES-GCM speed.

  Testing setup: Intel Core i5-8265U CPU (Skylake microarchitecture), with the base frequency of 1.6GHz and the hyper-threading, frequency scaling and turbo mode functionalities disabled

Performance Evaluation Details: MRAE-secure Transforms

- Implemented *encryption* algorithm of our and existing MRAE-secure transforms

  $$\mathsf{HtE} \circ \mathsf{RtC}$$ [BH22], CTX [CR22], PACT [BBD24]

  that target *the same* (i.e., strongest) CMT security in OpenSSL and wolfSSL:

  - Use AES-GCM-SIV as AE in OpenSSL and AES-SIV in wolfSSL
  - Use AES-CTR as E in OpenSSL and AES-GCM as E in wolfSSL
  - Use truncated SHA-512 as H + plain AES as F

- Performance measured as overhead over baseline (non-committing) AES-GCM-SIV / AES-SIV speed.

  Testing setup: Intel Core i5-8265U CPU (Skylake microarchitecture), with the base frequency of 1.6GHz and the hyper-threading, frequency scaling and turbo mode functionalities disabled